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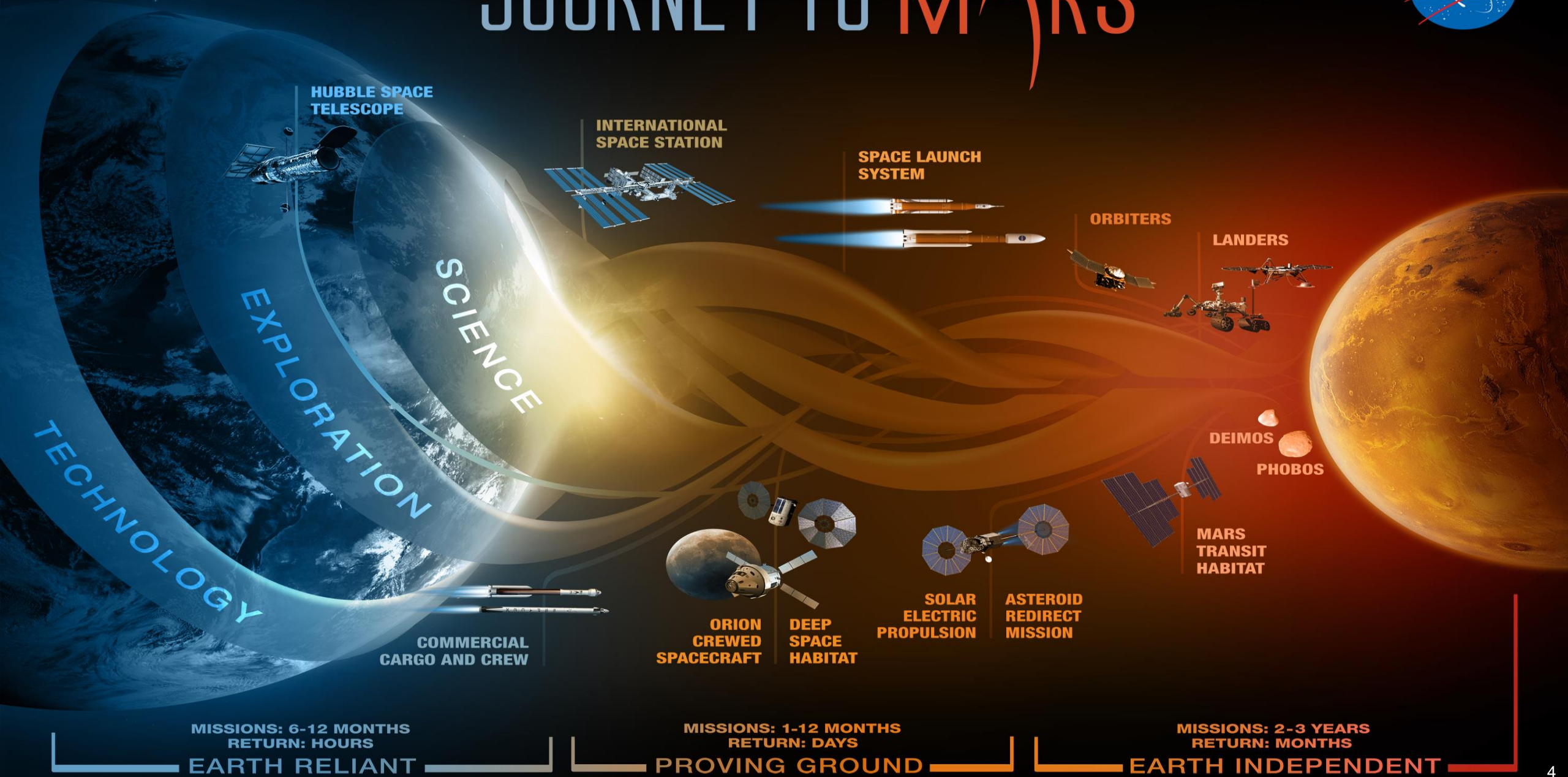
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NASA Kennedy Space Center

Occupational challenges in a Planetary Work Environment

ORP 2016 XVI International Conference on Occupational Risk Prevention

JOURNEY TO MARS



In-Situ Resource Utilization (ISRU)

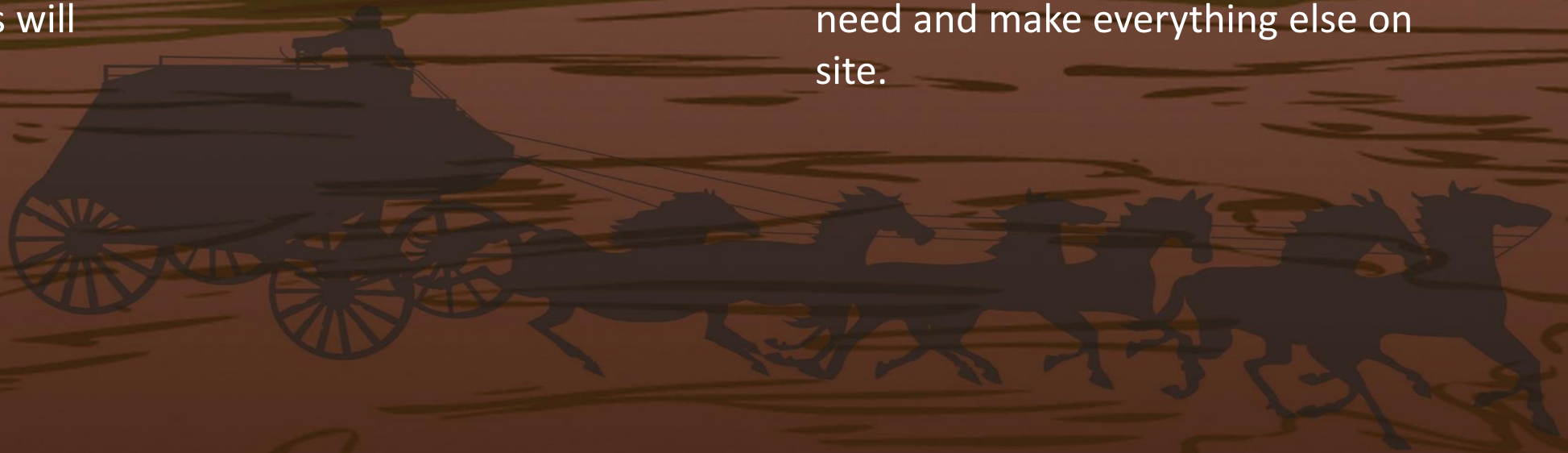
A composite image of space featuring Earth, the Moon, Mars, and a nebula. A satellite is visible in the foreground near Earth, and a small spacecraft is in the distance near Mars. The image is used as a background for the text.

Like explorers before us, we don't need to carry everything with us. In-situ resource utilization, or ISRU, is the idea of harnessing resources available at our destination, whether it is Mars, the Moon, an asteroid, or elsewhere.

Living off the land
...in space

A Pioneering Heritage

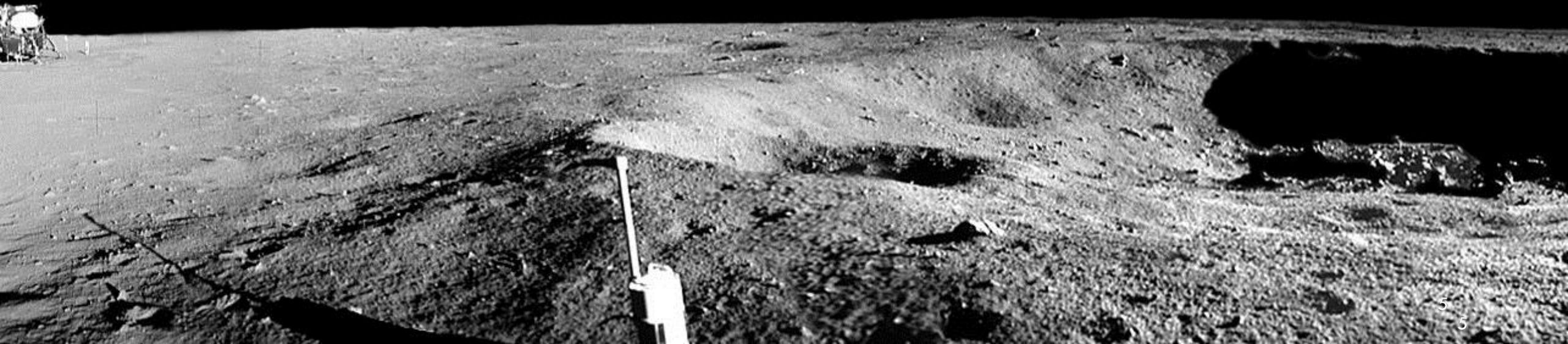
- Early settlers set sail to the New World in cramped ships, and once they arrived they faced harsh weather, lack of water, among other threats to their survival.
- Pioneering Mars will have similar challenges.
- We can't possibly bring everything we need to inhabit the Red Planet forever.
- We need to pack only the tools we need and make everything else on site.



REGOLITH AS A RESOURCE

We are exploring ways to exploit the regolith for as many uses as possible. We take one of two approaches:

1. Extracting resources out of the regolith, usually with chemical processes
2. Using the regolith as a raw material for building structures



In Situ Resource Utilization (ISRU)



- There is a great expense required to lift mass into orbit and beyond; how can we explore with less launched-mass?
- The solar system contains abundant resources; the atmosphere and soils of bodies. And sunlight!
- ISRU will mine these resources and convert them to mass saving commodities.
- We also look at converting wastes to useful commodities.
- If we want to **pioneer** in the solar system, we must use the resources that are in abundance!



Regolith & Atmosphere-Derived Resources

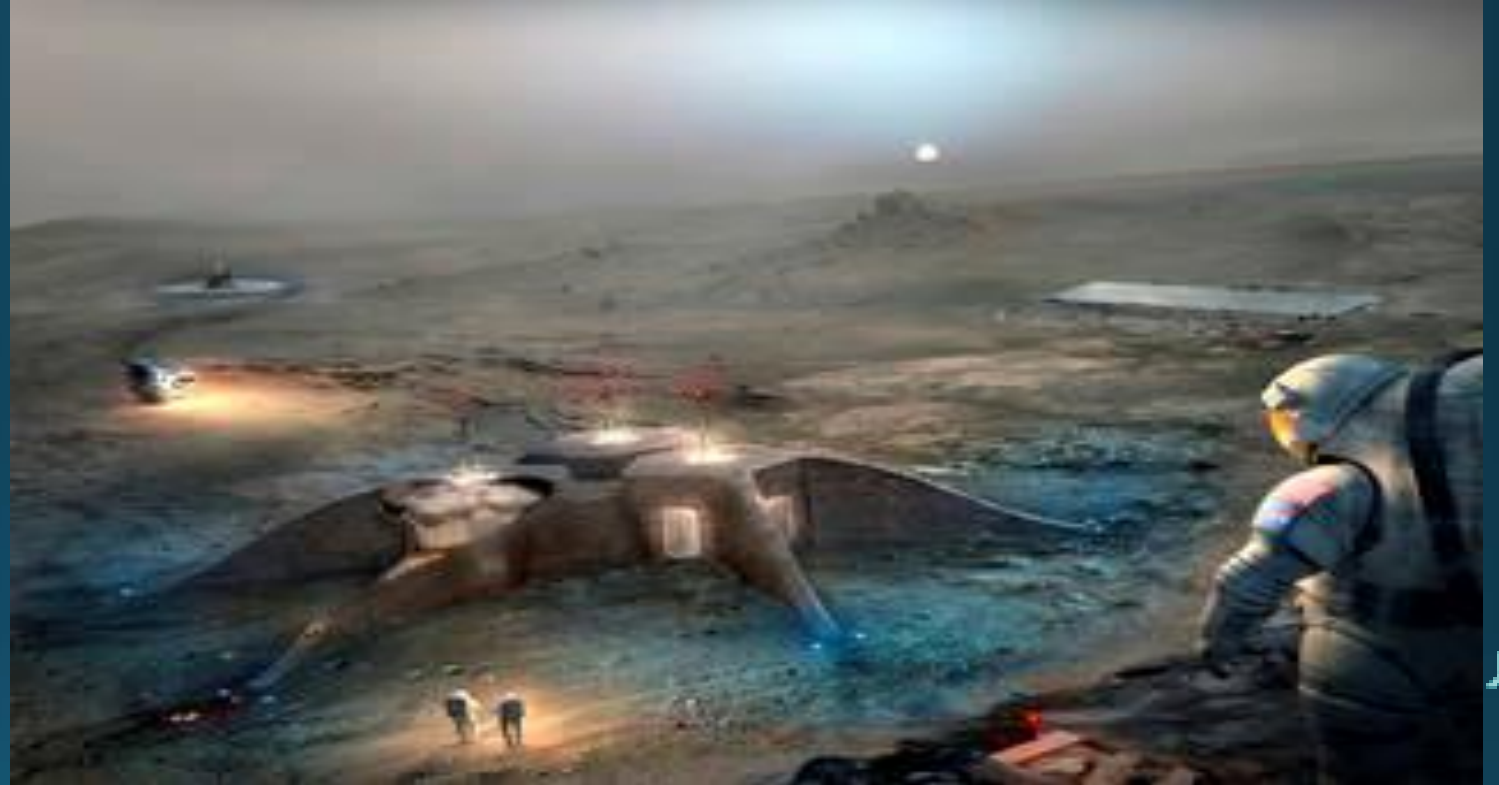
Potential sites for ISRU

- Moon
- Mars and it's moons
- Asteroids
- All other solar system bodies

CO₂ from the Mars Atmosphere

Water from the soil

- Permafrost
- Hydrated minerals in soils
- Buried Glaciers



Regolith & Atmosphere-Derived Resources

The primary resources and products that we have studied:

- Oxygen from regolith
- Water from soil volatiles
- CO₂ from atmosphere (Mars)
- Construction materials based on regolith (radiation shielding, landing pads)
- Berms, trenches and other excavation structures
- Regolith for greenhouse soils
- Metals from regolith
- Plastics from soil volatiles
- Food and oxygen from plants



Developing the Tools to Meet the Challenges

dust
TO **THRUST**

Mars Ascent Vehicle

A landing pad made out of 3-D printed regolith will keep the MAV from blasting a big hole with its rockets. The MAV will not have ascent fuel onboard when it arrives. By reacting carbon dioxide and hydrogen, methane can be made to fuel the MAV back off the Martian surface.



Processor

In a reactor, water will be extracted from regolith and combined with carbon dioxide to make drinking water, breathing air, and propellants like oxygen and methane.



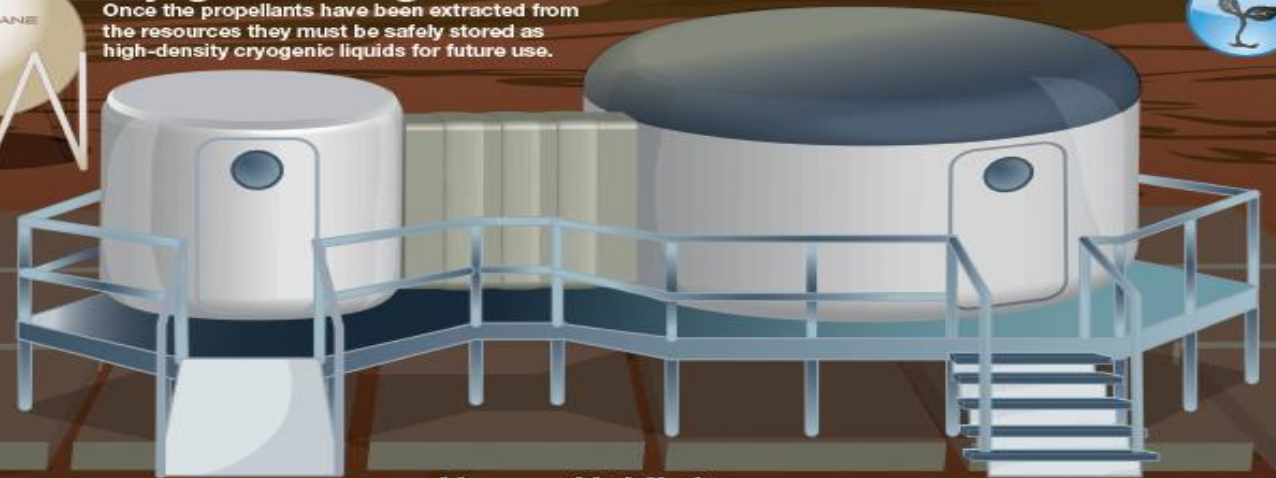
Plant Habitat

Water that has been processed from the Martian surface, along with the proper nutrient blend, can be used for growing plants for astronauts to eat. Plants also purify water and produce oxygen from respired carbon dioxide.



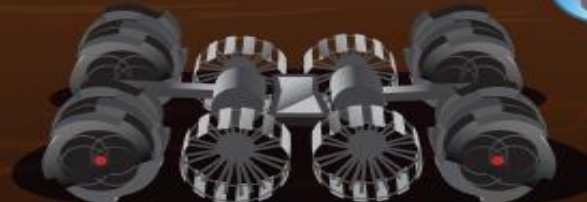
Cryogenic Storage

Once the propellants have been extracted from the resources they must be safely stored as high-density cryogenic liquids for future use.



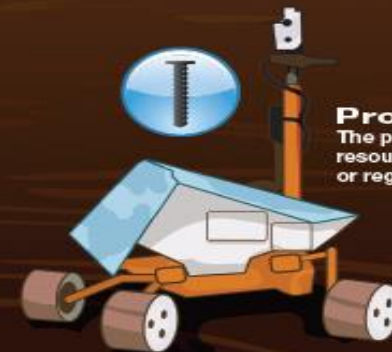
Human Habitat

Oxygen extracted from the soil and atmosphere can be used for breathable air and shields made from regolith or water may be used to help protect against radiation.



Miner

A robot will mine the regolith to obtain the resources locked inside.



Prospector

The prospector will drill to find resources buried in the Martian soil, or regolith.



MOON/MARS REGOLITH ROOM



A unique indoor facility featuring 120 tons of regolith simulant to support surface systems testing, especially in the area of robotic mining.

Martian Isolation Simulation



Trash to Gas

- Stabilization of all combustible waste, including human wastes
- Volume and mass reduction of stored waste

**For a crew of four over one year,
the waste can be used to:**

- Produce up 1 500 kg of methane
- Produce up 300 kg of water



Waste Storage on ISS



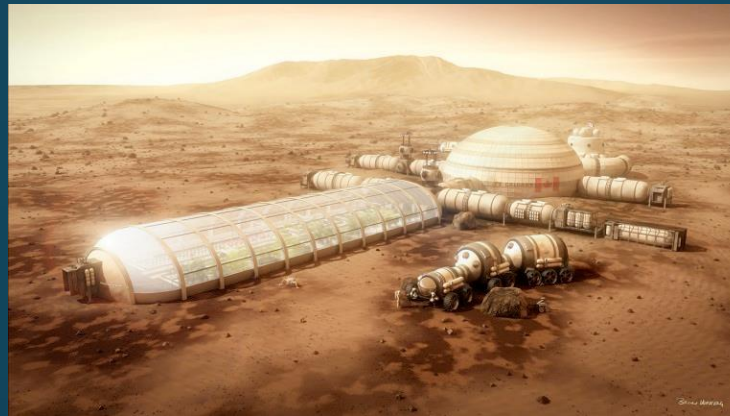
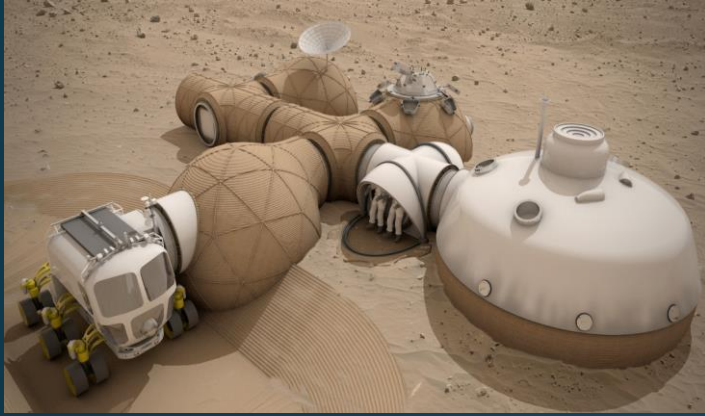
Food waste "football"

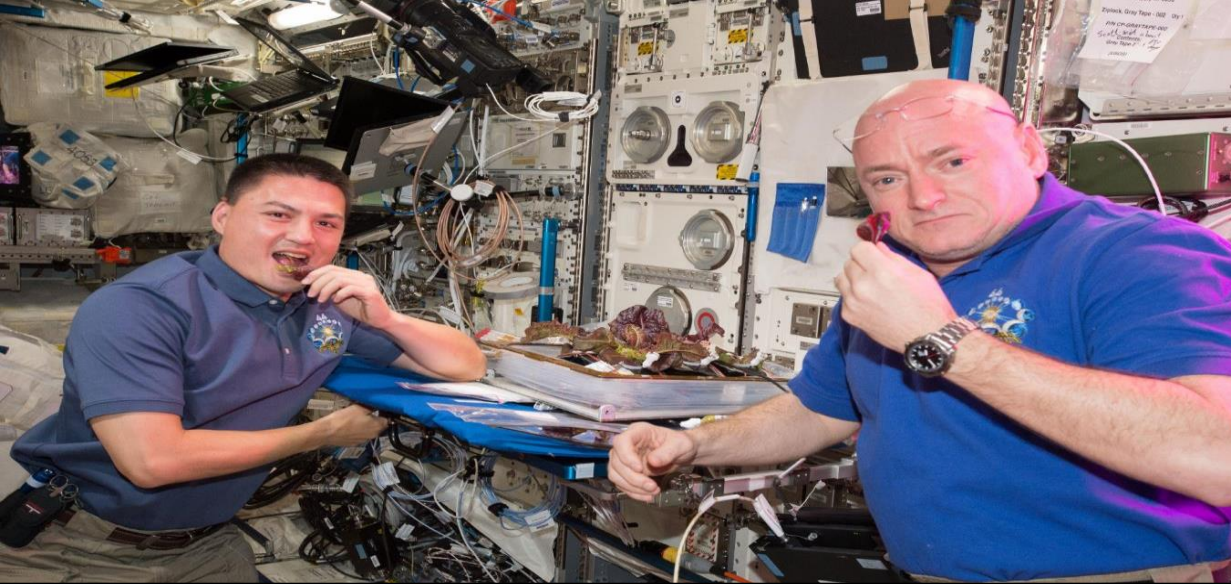


Oxygen
Water
Methane



MARS - Advanced Habitats Shelters





Growing Food in Space

Red Lettuce

Swiss Chard

Snow Pea

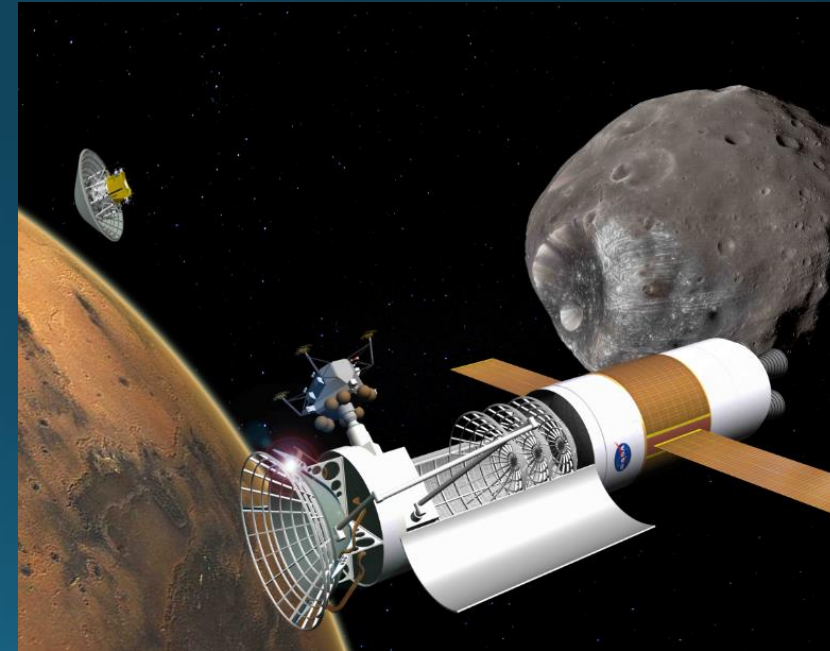
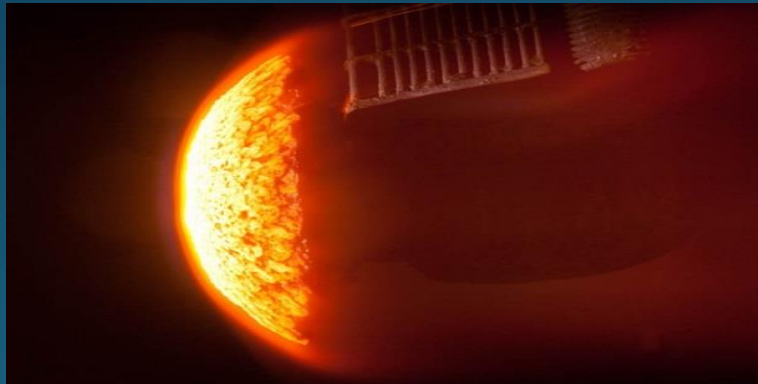
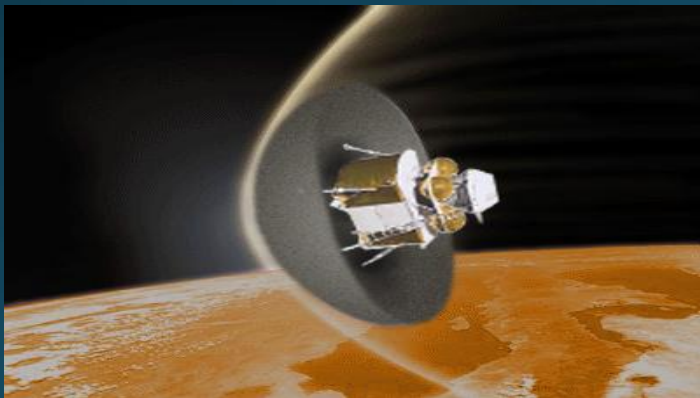
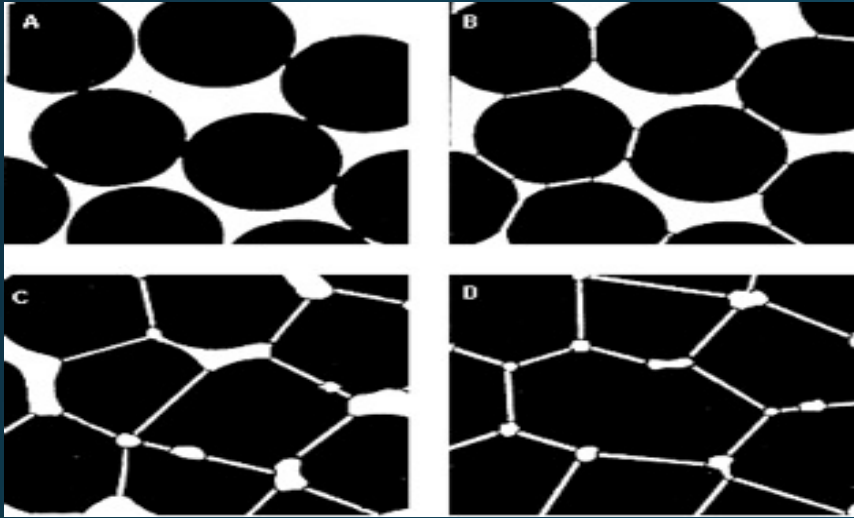
Dwarf Chinese Cabbage

Radish



3-D Printing/Additive Manufacturing from Regolith-derived Materials

Heating the moon dirt to just-below-melting temperatures (1200-1500 °C) makes the dirt stick together. Robotic 3D printers can then build walls of a habitat, or launch pads, paved roads etc.



Regolith-derived heat shield sample undergoing flame testing at ARC; regolith samples post-test; artist concept. Image Credit: NASA/KSC



“ WE DON'T HAVE A RESOURCE PROBLEM.

WE HAVE AN *IMAGINATION* PROBLEM.

”

-DR. PHIL METZGER



Questions?

